Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

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Summary

This millennium's Air Traffic Management (ATM) challenges can only be faced with a new paradigm for ATM research in Europe. The rising delays, the legitimate concerns over ATM safety (collision risk) in the air as well as on the ground and the growing environmental pressure necessitates the review of ATM R&D performance in Europe and the adoption of a new way of R&D co-ordination. It is argued that a rich diversity of ATM R&D ("pluriformity") is necessary to create a fruitful basis for ATM innovation. It is important that clear goals are set to the desired ATM performance and that a strong central direction will be needed to co-ordinate ATM R&D in Europe and to couple the R&D results to the targets. This in turn will demand the reshaping of the landscape of R&D providers into clusters with their own special expertise to combat fragmentation of R&D, whilst maintaining competition in the areas of innovative and applied R&D.

Contents

(20 pages in total)

1 What has the past R&D brought us?

The past, say 25 years of Air Traffic Management Research and Development have brought innovations to the ATM world that cannot be disregarded. They have had a major impact on the reduction of cost and the way the ATM process is being handled and expanded. R&D was partly responsible for us being able to accommodate the traffic growth there has been in the world.

In the following areas, significant progress has been made:

Communication, Navigation, Surveillance area
- Enhanced radars, and Multi- Radar Tracker and Server (ARTAS)
- 8.33 KHz channel separation
- GNSS
- Air Ground Datalink
- SSR Mode-S
- ADS-B
- VDL Mode 4

Surface Traffic Management
- Conflict detection: taxiway conflict monitors, runway incursion alert system
- Surface Movement Guidance Control Systems: planning systems

Air Traffic Control
- Conflict detection: Short Term Conflict Alert (STCA), Medium Term Conflict Detection (MTCD), Highly Interactive Problem Solver (HIPS)
- Arrival Management: COMPAS, MAESTRO, CTAS (in the USA)
- Converging Runway Display Aid
- Departure Management:
- Flight Data Processing Systems
- HMI: Large Colour Displays, input devices, stripless environment
- Controller Assistance Tools

Flow Management
- CFMU
- Multi-sector planning
- Fast time modelling of Air Traffic Movements (e.g. TAAM, SIMMOD, other)

Flight Management
- 4D FMS
- Navigation Databases

Safety Management

- Safety Management Systems
- Collision Risk Estimation (Reich, TOPAZ)
- Collision Risk Assessment techniques
- Safety Regulation Commission (SRC)
- TCAS
- ACAS

Environmental Control

- Noise hindrance models
- Third Party Risk models

It is safe to state however, that the majority of traffic growth has been accommodated by opening new sectors, putting more controllers to the task, and enhancing the productivity per controller. Some of the innovations, like 8.33 KHz channel separation, more accurate altimeters or GNS Systems acted as enablers on which the traffic growth could be safely accommodated.

2 The Plan-Do-Check-Act cycle applied to Air Traffic Management R&D

One could model the transformation of Air Traffic Management (whether it be flow management, surface traffic management or any other part of ATM) in a particular instantiation of Deming's Cycle (originally called the Shewhart cycle in 1939); which was created for process improvement and originally applied successfully in the 1950's in Japan: Plan (Evaluate the problem, formulate a strategy and plan to fix the problem), Do (execute the R&D necessary to achieve the desired state, then validate the solution and implement the change in the ATM process), Check (study to see that the implementation has indeed improved the situation) and, Act (conserve the implementation and create a larger basis for a more wide-spread application; update the quality manual and lessons learned).

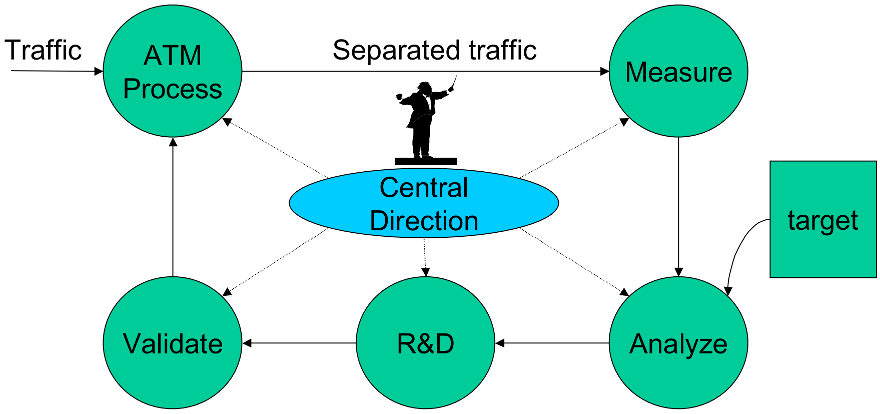

Fig. 1. Plan-Do-Check-Act Cycle applied for the Air Traffic management R&D.

The Deming cycle is widely understood to apply at virtually all organisations and/or processes. It is not so much the precise naming of the individual elements that counts here: it is the notion of an improvement process where all relevant elements are working together. And this is not what happened in the past 25 years: there has been plenty of structure and direction at the local level - but not nationally or internationally; at that level it was more like unstructured, random research that provided the basis of innovation for ATM. Some of the elements described in fig. 1 have representations in today's Europe: the Performance Review Commission (PRC) could be regarded as the 'Measure' process. The Eurocontrol R&D Review Group (now disbanded) could have figured as the 'Analyse' process; however earlier attempts to use the R&D Review Group for R&D co-ordination have failed; there was no link or attachment from the R&D Review Group members to a widely supported ATM strategy. There was no grip on direction of research other than advisory. Despite the availability of the ATM2000+ strategy, there are only non-specific objectives, like more safety, less delay, etc. and this does not translate into a clear target system that all stakeholders will support. Moreover, stakeholders come in many forms and have different, sometimes short-term objectives.

Note that in this figure there is a place for a central director, a 'conductor of the orchestra', which is normally obvious in a PDCA cycle, because it usually involves a single-actor business or industry. Air Traffic Management however, is by nature very much a multi-actor environment, where multiple actors are each responsible for only a part of the total ATM process. To complicate matters further, it has also by nature trans-national characteristics that make it extremely difficult to progress. Therefore, the role of the conductor is very difficult to implement in the European ATM R&D arena.

3 From unstructured research to implementation validation

The improvements to the ATM process have thus not been a result from the cycle as described above but have been the product of relatively unstructured R&D; that is, European-wide R&D not deliberately and intentionally following a PDCA cycle. Five types of R&D can be distinguished:

Fundamental Research
This forms the backbone of many of the advancements in any type of science. It is frontier research in engineering, computing, mechanics, mathematics, management, etc. It is an absolute necessity to advance the state of the art in every type of R&D in later stages. All further ‘phases’ of R&D rely on the results of this type of research. It is not directed at Air Traffic Management.
Characteristics: low cost, small size, continuous (no beginning and no end), high risk, no guaranteed outcome, unknown application, no specified problem statement.

Strategic Research
(Or Basic research) This is the basic research that is being done to further advance understanding to provide the foundation for applied ATM R&D. In general, the outcome is still unknown but there may be a potential useful application in several years from now.
Characteristics: low cost, small size, in general continuous, medium risk, no defined customer, directed at ATM in general but not a specific application.
Examples: speech recognition in ATC, mobile datalink communications, advanced system integration tools.

Innovative Research
This is where innovative or ‘wild’ ideas are inserted in the R&D life. The subject of innovative research varies wildly, but in general is formulated against the ATM problem statement.
Characteristics: low cost, small size, non-continuous, takes ideas from other business areas, high risk, outcome unstable, unknown application, but directed at ATM in general, problem statement only vaguely formulated.
Examples: windscreens beside a runway to reduce crosswind, the initial Free Flight ideas.

Applied Research and Development
In this phase usually a specific customer wants to have something researched or developed for a particular application in ATM.

Characteristics: medium size/cost, specified in time (with beginning and end), likely or potential yield, customer is known, directed at a specific process of ATM, problem statement is clearly specified.
Examples: new flow management algorithm, Arrival Manager, Speech processing for Air Traffic Controllers.

Integration and Pre-operational validation
The final phase before implementation in the real ATM process. Usually this is the Development phase, rather than Research. From here, a strong link with the industry is necessary to ensure that the goods (commercially) arrive in the ATC operations room.
Characteristics: high cost, large size, targeted at very specific application, known cost/benefit and return in investment, customer is known, low risk. Exact problem statement formulation.
Examples: testing a new operational centre, a new Flight Data Processor System, new ATC console layout, new route structures, RVSM final phase testing.

This zone of convergence from fundamental research to pre-operational validation is shown as:

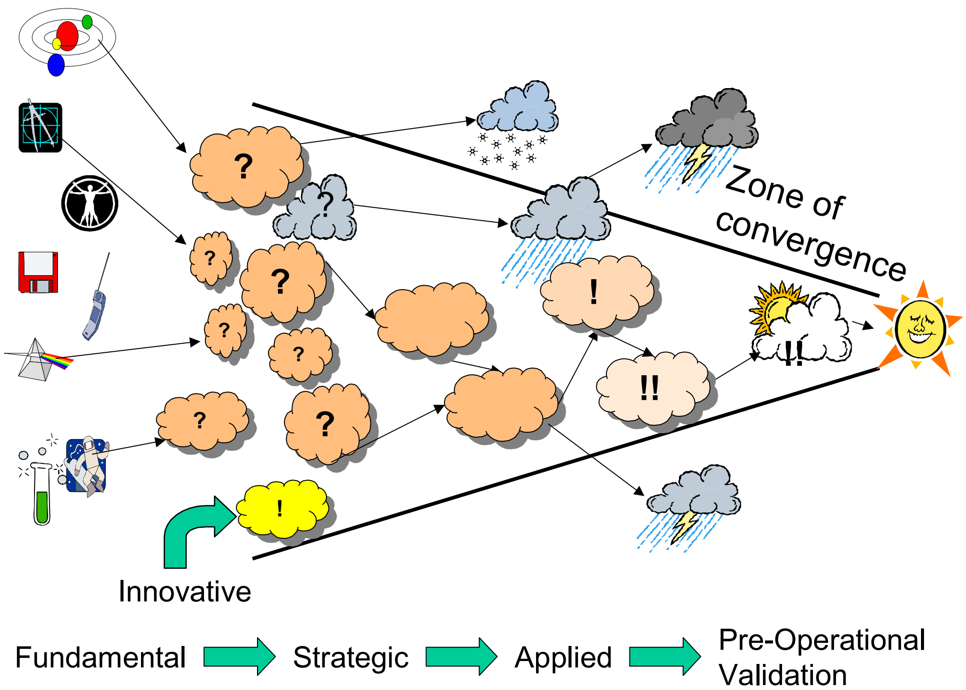

Fig. 2. In order to arrive at one or more successful applications, a lot of R&D takes place before that. Not all R&D projects will have a successful operational impact.

It is clear that in order to arrive at very specific developments in ATM, a lot of R&D is needed to carry this pyramid of R&D forward to a stage where one or more applications are actually successful and reach the implementation stages. Note that R&D is never carried out in areas where no success is expected beforehand. Hindsight is a wonderful thing and early ideas are not always productive. The CARE (Co-operative Actions of R&D in EUROCONTROL) Innovative Actions programme by Eurocontrol will have to take aboard an enormous amount of ideas, in order to have just one that will get carried through the pyramid of Research and Development stages and reach the implementation phase. However, as a role model it sets an example for the rest of the member states to follow.

It must be clearly stated that the Plan-Do-Check-Act cycle as depicted here does not apply to the fundamental and innovative research phases: in those phases the problem statement cannot be exactly specified and no plan can be made as to its implementation. Furthermore, the optimum way of R&D is a fine balance between technology-push and demand-pull. There is currently not enough technology-push, but also there is a lack of demand-pull by the ANSPs and/or Eurocontrol.

4 The respective roles of the 'R&D providers'

The ATM R&D is done by a variety of ‘ATM R&D providers’. Taken from the ARDEP (2000) database, there are not less than 332 ATM R&D providers! They are classified according to the following table:

PARTNERS' GROUP	*SECTOR*
Aircraft Manufacturer	INDUSTRY
System/equipment Manufacturer	
Software House/System Integrator	
R&D Centre of Expertise (including laboratories and universities)	NON-INDUSTRY
ATM Service Provider	
Airport Operator	
Aircraft Operator	
Consultancy	
Support Service Provider	
Representative Body	
Government Body (national or supra-national)	
Regulator	

Fig. 3. Classification of Research and Development ‘providers’ according to ARDEP 2000.

There are many ATM R&D providers in Europe and a clear distinction must be made between the R&D entities: universities and large R&D research labs, consulting firms, R&D centres, Industry, Air Navigation Service Providers (ANSP). More than one third of these R&D providers are classified as industry. The core providers each have their own domain in the respective R&D phases (fig. 4).

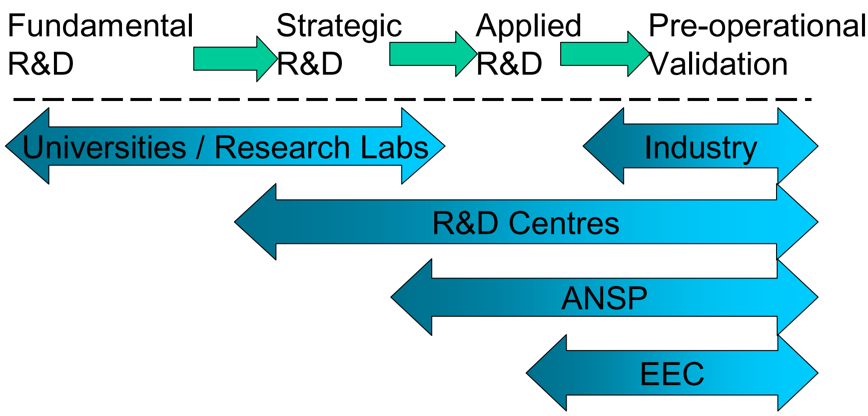

Fig. 4. Different R&D providers are covering different phases of ATM R&D

It is no surprise that Universities and Research labs should provide the fundamental research and usually this is a state funded activity. R&D centres will have, depending on the specific entity, a broad range, but with a clear focus on applied R&D and in exceptional cases going as far as the implementation phase. The Air Navigation Service Providers (ANSP) play a special role in Europe, since they will be running the actual operation and are thus closest to the user and the requirements. Also there is a strong commitment to a successful implementation. In many cases, ANSP focus on the issues that are particular for their situation of airspace complexity and airport configuration. Their R&D may therefore not always be of European-wide interest. Note that the EEC has a specific place in this fig. 4, at the end of the spectrum, with the main focus clearly on pre-operational validation and applied R&D. The industrial partners, lastly, usually have little commercial opportunity to earn back the investment done on Innovative R&D and sometimes also Applied R&D.

5 The PHARE-X Association

The Programme for Harmonised ATM Research in Eurocontrol (PHARE) ran from 1998 until 1989 and proved that a 4D ATM concept had certain feasibility. PHARE had a number of notable successes. It formed for a significant part the basis for the ATM 2000+ strategy document. The Boeing ATM plan, 3 years later, adopted the 4D ATM strategy for the future and added satellite based navigation as a refinement of the navigation concept within 4D ATM. Also, various elements of the PHARE program, although aiming at a concept around 2015, are reaching already implementation stages in other projects.

The main partners participating in PHARE learned that the program had, apart from the technical merit, brought many of the researchers together and that all had benefited from the diversity of the R&D done in different places. The creation of The PHARE-X Association (TPA) expressed their wish to preserve this for future work. The members of PHARE-X are the ATM service providers and research institutes who form the mainstay of European ATM Research and Development. They have joined forces to support ATM R&D and innovate the state of the art ATM process. For that, the association actively encourages co-operation between members1 and associate members2 and stimulates the conception of innovative R&D in Europe. Amongst its objectives are to provide continuity and consistency in ATM R&D, and to make more efficient use of scarce ATM R&D resources.

The PHARE-X Association (TPA) was formed early in 1994 and bids for calls of the respective framework programmes of the European Commission. Recently, TPA established the FARANDOLE consortium, with three additional partners, to bid for Eurocontrol Framework Contract tasks. The size and nature of some of the calls warrant that more than one partner will make a proposal for the work offered, and so multiple proposals are being offered to the client. This shows the usefulness of the diversity of the expertise available: more than one solution may be applicable to a given problem.

A particular strong point of The PHARE-X Association is the connection with the Air Navigation Service Providers (ANSP). Their research branches are members of TPA and create a strong link to the “users” and their requirements. A strong commitment for the result promotes that the product of ATM R&D can be adopted in the operations room as quickly as possible.

6 Fragmentation, Direction and Control

The case for a multi-formity of R&D nuclei is thus explained. What remains as a challenge is to address the current fragmentation of the R&D, and where unnecessary overlap between R&D exists. Certainly in the fundamental research and innovative research this is perfectly acceptable. But in the applied R&D for ATM, there exists fragmentation as well as overlap, which may be identified using the well-structured available information about ATM R&D in Europe (ARDEP). However, the ARDEP team recognizes that it is difficult to classify the R&D according to objective. A quote from ARDEP: “This raises the question as to whether the R&D activities are covering the real R&D needs of the Eurocontrol ATM 2000+ strategy”. There is a

[1] DNA, QinetiQ, DFS, DLR, NATS, NLR, Sofréavia
[2] SICTA

need for a better coordination, interchange and sharing of results concerning the study of the fundamental basis of ATC: the mental model of the controller, how to measure workload, etc.

It is noted that initiatives are under way in Europe to address the question of direction of ATM R&D. The Advisory Council for Aeronautics Research in Europe (ACARE), created after the advice of the Vision 2020 document, whose goal would be to develop and implement a strategic approach to European aeronautics research.

> *The ACARE will be composed of 25-30 members, including representation from Member States, the Commission and stakeholders. It will meet two to three times a year and will submit a Strategic Research Agenda (SRA) as well as its positions, opinions, recommendations and reports to all the relevant players. The primary mission of the ACARE will be to establish and carry forward the SRA, which will serve as a guide in the planning of research programmes, particularly national and EU programmes.*

This can be regarded as an attempt to effectuate (part of) the described R&D cycle in paragraph 2. Whilst it is an excellent attempt to structure the R&D in Europe in a much more effective way, it still lacks, however, the power of the central direction, the “conductor”, to make things actually work. ACARE is therefore in danger of failing to be able to conduct all parts of the PDCA cycle: control the measurement, do the analysis, plan the R&D, control the R&D, and check if the result of the actions do indeed improve the situation. These powers are typically most effectively exercised by the funding mechanism; Europe therefore needs to progress a further step beyond ACARE to set up an appropriate, European-wide funding mechanism that is centrally controlled or co-ordinated.

Quality & Affordability	Safety	Environment	European Air Transport System
Permanent trend monitoring	Flight hazard protection	Drag reduction through conventional and novel shapes	Innovative ATM operational concepts
Flexible cabin environments	Advanced avionics	Fuel additives	Advanced, intelligent and integrated ATM ground, airborne and space systems
Passenger services	Probability and risk analysis	Noise reduction	Rotorcraft integration in ATM systems
Anticipatory maintenance systems	Computational methods	Propulsion concepts	High density traffic systems capability in all weather conditions
Integrated avionics	Human error checking systems	Emission reduction	Airport capacity and advanced
ATM related airborne systems		Environmentally friendly production, maintenance and disposal	
Novel materials and structural concepts		Better aircraft/engine integration	
Lead time reductions			
Integrated design manufacturing and maintenance systems			
Advanced design methods			
System validation through modelling and simulation			
Concurrent engineering			

Fig. 5. Research challenges (examples) from the Vision 2020 to create a Strategic Research Agenda (SRA) for Europe. Highlighted are the elements where ATM R&D will play a major role

7 The future ATM R&D landscape

The challenge is thus to combat fragmentation whilst preserving pluriformity, diversity and richness of ATM research. The picture emerging is a conglomerate of R&D providers, each covering a broad spectrum of R&D issues, but also each specialising in a particular area of R&D (e.g. controller tools, safety research, ATM systems architecture, ground surveillance and control, etc.). There will be a strong link with industry, to create the highest possible chance that the R&D reaches the operations floor. This conglomerate of multiple ”members” will be dispersed over Europe, as it is now, but will receive strong direction from a central body, in charge of the ATM R&D cycle as described in fig. 1. All stakeholders will subscribe to this strategy, as they realize that their individual strategies will not lead to the required capacity increase and additional safety.

The members of these clusters will not forsake any national duties they may have, and still operate within a competitive environment where the fundamental, innovative, and applied R&D is concerned. This competition will no longer be applicable in the phases of pre-operational validation, when large, costly installations are being used and where the most efficient use of scarce resources must be made.

These R&D clusters should have a co-operative attitude towards working with airlines / military airspace users and airports and ANSPs. This working closely with the client is essential for the commitment to the solution of the problems. The Eurocontrol Experimental Centre in Brétigny should have the task of being the final frontier before industrialisation of R&D results takes place.

It is to be expected that the current flow of corporatisation (or privatisation) is also setting in motion a cost-reduction process. The ANSPs have the luxury that in principle they are operated on a full cost-recovery scheme, and since they have a monopoly in their own airspace, there is no life-threatening incentive to reduce costs. But after the events on the 11th of September 2001, they are under heavy pressure to reduce costs. In future, the ANSPs will seek alliances, will try to reduce costs more vigorously than before and in doing so, will come to the conclusion that it is no longer attractive to exactly specify the systems that will fit their operations, but rather will adapt their operations to match the systems they can buy off the shelf. This will be a very important development. The airspace users (i.e. airlines) will have a strong and joint input, much more co-ordinated and visible than they do now. By then the industry can respond to a co-ordinated demand from the customers, and a larger technology-push and demand-pull effect will be observed. There is a crucial role to be played by a central body, to make sure that this co-operation between ANSPs to harmonise their requirements towards industry and R&D providers will actually take place.

For the future of the European airspace use, the reduction of delays, the increase of safety, the improvement of efficiency, it is necessary that the Plan Do Check Act cycle, or similar initiatives which couple the performance of the total ATM process to the demands made upon the R&D capabilities in Europe, is actually established. As shown in fig. 1, this requires the role of the central conductor to be fulfilled. Although there are initiatives that show some of the characteristics of central control, the total cycle remains uncontrolled.

The ACARE initiative is a good attempt to direct the research in a specific direction, but has no direction over the performance measurement of ATM, nor on the ATM process itself. In setting up the Strategic Research Agenda (SRA), ACARE will hopefully create a European wide effort of committing the European countries to the right R&D topics. But as such, it should be classified as a well organized technology push.

The Eurocontrol Agency has shown some good initiatives to co-ordinate the R&D in Europe, as well as with the FAA, but so far did not succeed in coupling the existing R&D in various countries to the Eurocontrol ATM 2000+ strategy. So far, it is therefore to be classified as a good information exchange for researchers and provides an excellent platform to exchange ideas. The FAA/Eurocontrol Action Plans generally have as their most noticeable result just that, and this is disappointing. The Action Plans should be restructured so that they follow a widely adopted ATM strategy and a good demand-pull is created. With no widely adopted strategy available, this will be quite a challenge for some time to come.

Eurocontrol's potential role of impartial central conductor is hampered by the fact that they are also part of the R&D providers: in Brussels headquarters, but more relevant with the Eurocontrol Experimental Centre (EEC). This is mainly a problem in the R&D phases before integration and pre-operational validation.

A necessity for a central conductor body being identified, and concluding that no entity in its present form can fulfil this role, a process should be started at European Commission level to create it.

There is an interesting development going on with the Boeing ATM initiative; this is a proposal where a strong central direction is applied to the total process of ATM and to all relevant actors in the business, and with a clear common goal which (sometimes too small) individual entities cannot always fully support because there will be one or more elements against their (commercial) interests. This initiative has a chance to force global standardisation and co-ordinate the necessary R&D with success. There will be a strong demand-pull combined with a suitable technology push (satellite navigation) and many of the stakeholders will be combined into one organisation.

8 Summary and Conclusions

It is argued that relatively unstructured ATM R&D was responsible for the technological improvement over the last 25 years of ATM development. Notwithstanding that, there is a firm belief that R&D can be more effective with a proper mechanism for funding and co-ordination of the R&D, in combination with a good strategy for development and control over measurement of the effect. In Europe, the Vision 2020 and the ACARE are good initiatives that strive to achieve the strategy (Strategic Research Agenda).

The respective roles of Fundamental R&D, Innovative R&D, Applied R&D and Pre-operational Validation as phases of technological development should be distinguished and its characteristics recognised. The various ATM R&D providers (Universities, R&D Centres, Air Navigation Service Providers, Eurocontrol Experimental Centre and Industry), each have different, but complementary roles according to the characteristics of the R&D phases.

Innovative, high risk, low cost research is necessary to provide a good basis for successfully applied R&D. It is important to maintain the richness and diversity of innovative and applied ATM R&D, whilst limiting the unnecessary overlap between pre-operational validation and final experimentation.

It is of paramount importance for the future of the European airspace, the reduction of delays, the increase of safety and the improvement of efficiency that a fine balance is struck between technology-push and demand-pull. For the Research & Development providers this means they are to be structured into strongly linked ATM R&D centres, where competition of ideas exists but no where fragmentation or unnecessary overlap remains with large Applied R&D, Integration and pre-operational validation (centres of expertise). The Strategic Research Agenda has to be adopted by these R&D providers, for which an appropriate and elaborate European and member states funding mechanism is required.

A necessity for a central conductor body being identified, and concluding that no entity in its present form can fulfil this role, a process to create it should be started at European Commission level.

Acronyms

4D	Four - Dimensional (latitude, longitude, altitude, time)
ACARE	Advisory Council for Aeronautics Research in Europe
ACAS	Airborne Collision Avoidance System
ADS-B	Automatic Dependent Surveillance – Broadcast mode
ANSP	Air Navigation Service Provider
ARDEP	Analysis of Research and Development in Eurocontrol
ATC	Air Traffic Control
ATM	Air Traffic Management
CFMU	Central Flow Management Unit
COMPAS	Computer Oriented Metering Planning and Advisory System
CTAS	Centre Tracon Automation System
DFS	DFS Deutsche Flugsicherung GmbH
DLR	Deutsches Zentrum für Luft- und Raumfahrt
DNA	Direction Navigation Aérienne
EEC	Eurocontrol Experimental Centre
FAA	Federal Aviation Administration
FARANDOLE	Consortium name
FDPS	Flight Data Processing System
GNSS	Global Navigation Satellite System
HIPS	Highly Interactive Problem Solver
HMI	Human Machine Interface
MAESTRO	CENA / Sofréavia's Arrival Manager System
MTCD	Medium Term Conflict Detection
NATS	National Air Traffic Services
NLR	National Aerospace Laboratory
PDCA	Plan Do Check Act
PHARE	Programme for Harmonised ATM Research in Eurocontrol
PRC	Performance Review Commission
R&D	Research & Development
RLD	Rijksluchtvaartdienst
RVSM	Reduced Vertical Separation Minima
SICTA	Sistemi Innovativi per il Controllo del Traffico Aereo
SIMMOD	Simulation Model
SRA	Strategic Research Agenda
SRC	Safety Regulation Commission
STCA	Short Term Conflict Alert

TAAM ®	Total Airspace and Airport Modeler
TCAS	Traffic Alert and Collision Avoidance System
TOPAZ	Traffic Organisation and Perturbation AnalyZer
TPA	The PHARE-X Association
VDL	VHF Data Link